Using ArcGIS to Link Urban Storm Water Software (SWMM) and Economic Flood Damage Analysis Software (HEC-FDA)

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US Army Corps of Engineers
Louisville District

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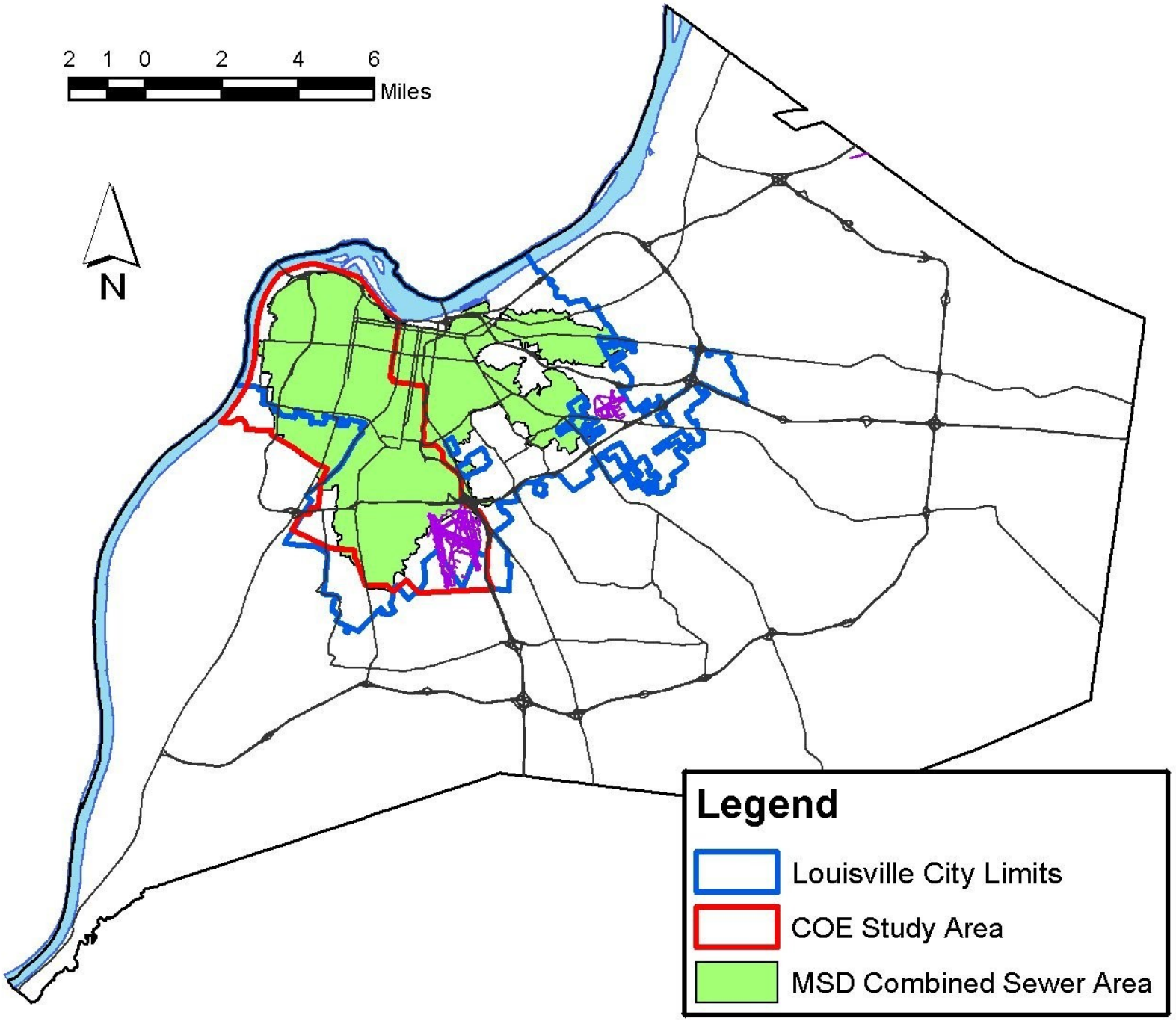
Introduction

- HEC-FDA (Flood Damage Analysis) software traditionally used in riverine situations
- The Louisville Southwest Flooding study applied HEC-FDA model to urbanized area with combined sewers
- Municipal GIS (LOJIC) consortium provided much of the required base data
- GIS provided link between hydraulic modeling (SWMM) and economic analysis (HEC-FDA)


2 1 0 2 4 6
Miles
N
Legend
Louisville City Limits
COE Study Area
MSD Combined Sewer Area

Study Area

- 32.0 square miles
- Highly urbanized, fully developed
- 68,000+ structures
  - 89.3% residential, 6.0% commercial / industrial, and 4.7% property tax exempt (e.g. schools, churches, government buildings)
- Combined sewer model
  - 216 miles of pipe over 18” diameter
  - 4,800+ manholes

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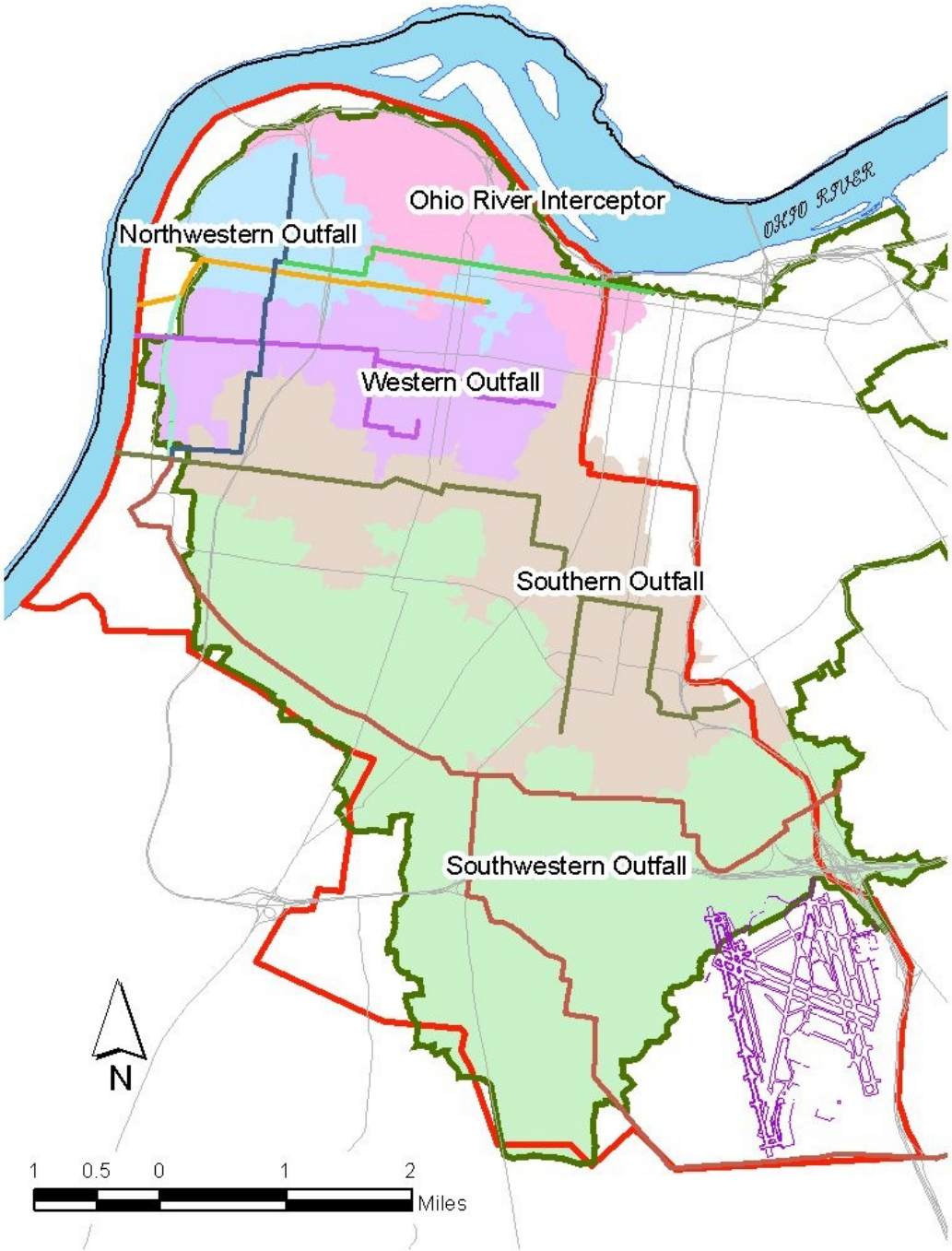

Ohio River Interceptor
Northwestern Outfall
OHIO RIVER
Western Outfall
Southern Outfall
Southwestern Outfall
N
1 0.5 0 1 2
Miles

Project History

- Several severe flooding events in 1980s & early 1990s
- Federal funded reconnaissance study in mid-1990s
- Next stage was feasibility study

Project History

- Feasibility study began in late 1998
- Hydrology & Hydraulic analysis using SWMM
- Local sewer district had model of 42” diameter pipes and larger
- Model was extended to include all pipes 18” and greater

Project History

- SWMM model used to determine Hydraulic Grade Line (HGL) and discharge from manholes
  - Eight events - 1-yr, 2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr, and 500-yr
  - 3 Ohio River stages – normal, 2-yr, & 10-yr
- Initial H&H completed in Spring, 2001

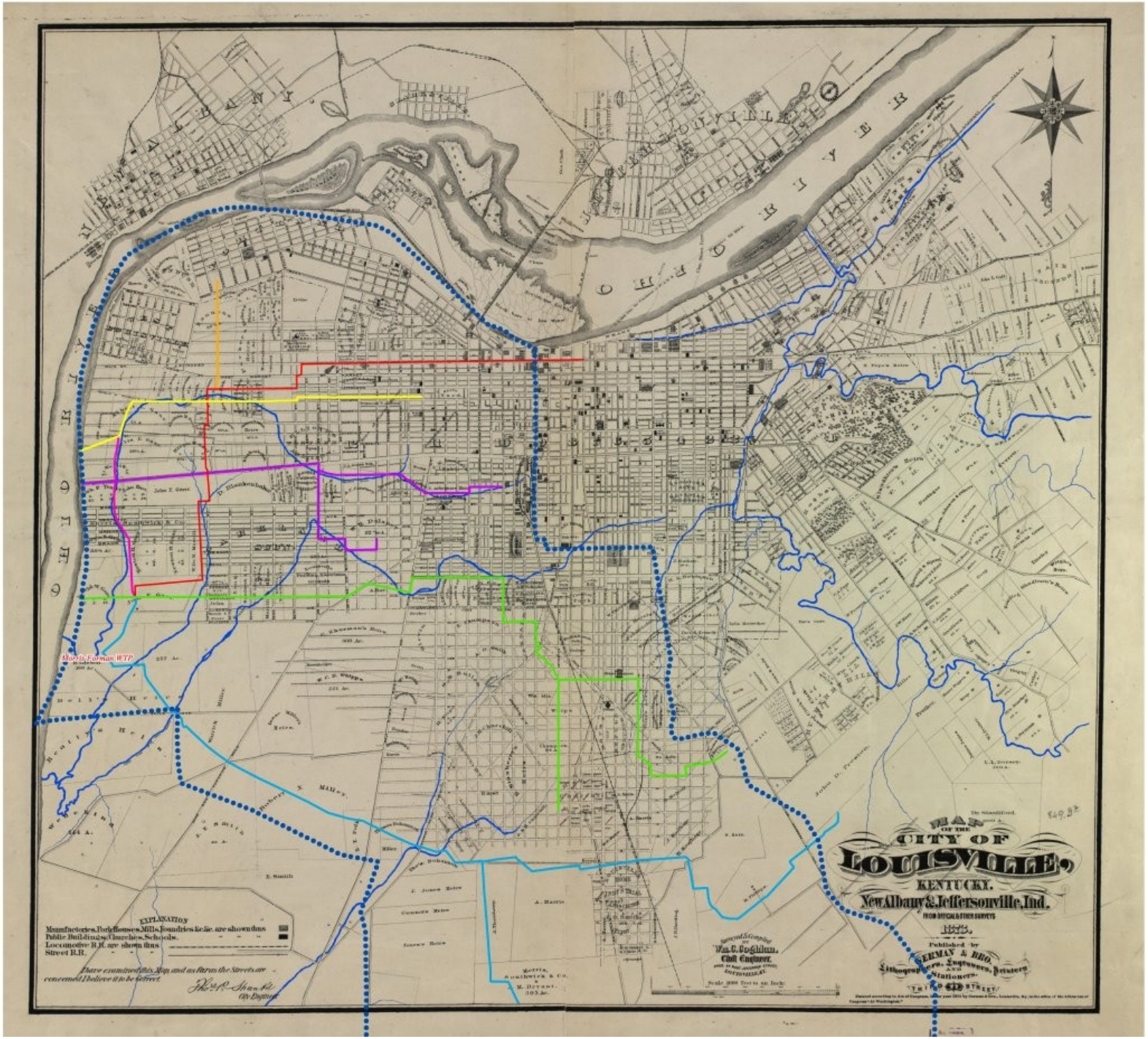
Project Scope

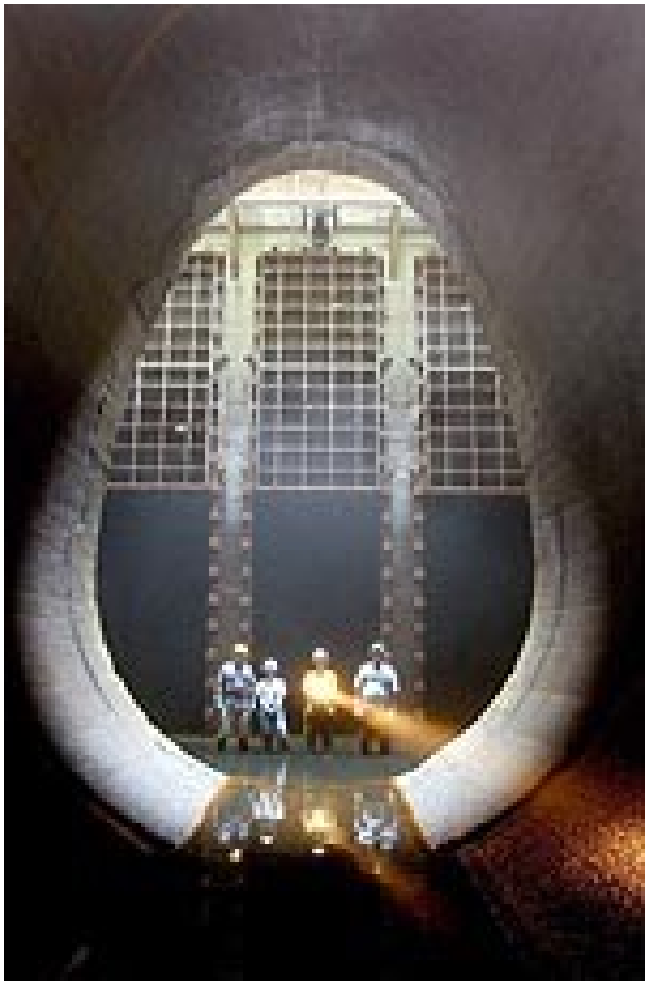
- For the economic analysis, damages divided into two major categories
  - Basement flooding
  - Surface flooding
- For basement flooding, compare basement floor elevation with Hydraulic Grade Line (HGL) at appropriate node
- For surface flooding, need to convert the volume surcharged from the manholes to geographic extent and maximum water surface elevation (stage)

Unique Flooding Characteristics

- Enclosed pipes replaced natural streambeds

Riverine	Enclosed System
Stream	Outfall
Reach	Node
Thalweg	Invert


MAP
OF THE
CITY OF
LOUISVILLE,
KENTUCKY.
New Albany & Jeffersonville, Ind.
FROM OFFICIAL & OTHER SURVEYS
1875.
Published by
GERMAN & BRO.
Lithographers, Engravers, Printers
AND
Stationers.
EXPLANATION
Manufactories, Pork Houses, Mills, Foundries &c &c. are shown thus
Public Buildings, Churches, Schools.
Locomotive R.R. are shown thus
Street R.R.
I have examined this Map and as far as the Streets are concerned I believe it to be Correct.
Scale 1000 Feet to an Inch.
Morris Forman WTP



Hydraulic Uncertainty Input

- Entering equivalent record length for 4,800+ reaches, 3 river stages, each alternative
- Custom HEC application, AutoProb, enters equivalent record length for each reach

Associating Structures with SWMM Manholes

- Need to associate each structure with a SWMM modeled manhole to compare the maximum water surface elevation (WSE) for each of the 8 designated events
- HEC-FDA statistically compares these WSEs with the basement elevations to determine depth of flooding

Associating Structures with SWMM Manholes

- Developed an ArcInfo Macro Language (AML) to associate the structures with a manhole
- Algorithm
  - Find closest sewer segment; Check to see if upstream or downstream node is modeled
  - If only one modeled, associate with structure
  - If both modeled, associate closest with structure
  - If neither modeled, trace downstream until modeled manhole is located
- Run AML, review, and manually adjust anomalies

SOUTHERN PKY
15 "
27 "
18 "
15"
18"
12"
8"
24"

Determination of Surface Flooding Stages and Extents

- SWMM can model surface flooding at nodes by defining stage / volume / depth (head) relationship at each node
- SWMM will calculate stage / volume / depth (head) at each timestep
- Would be extremely costly to develop stage / volume / depth relationship at each node (4,800+)
- For less frequent events, interbasin transfer prohibits SWMM from working correctly

Determination of Surface Flooding Stages and Extents

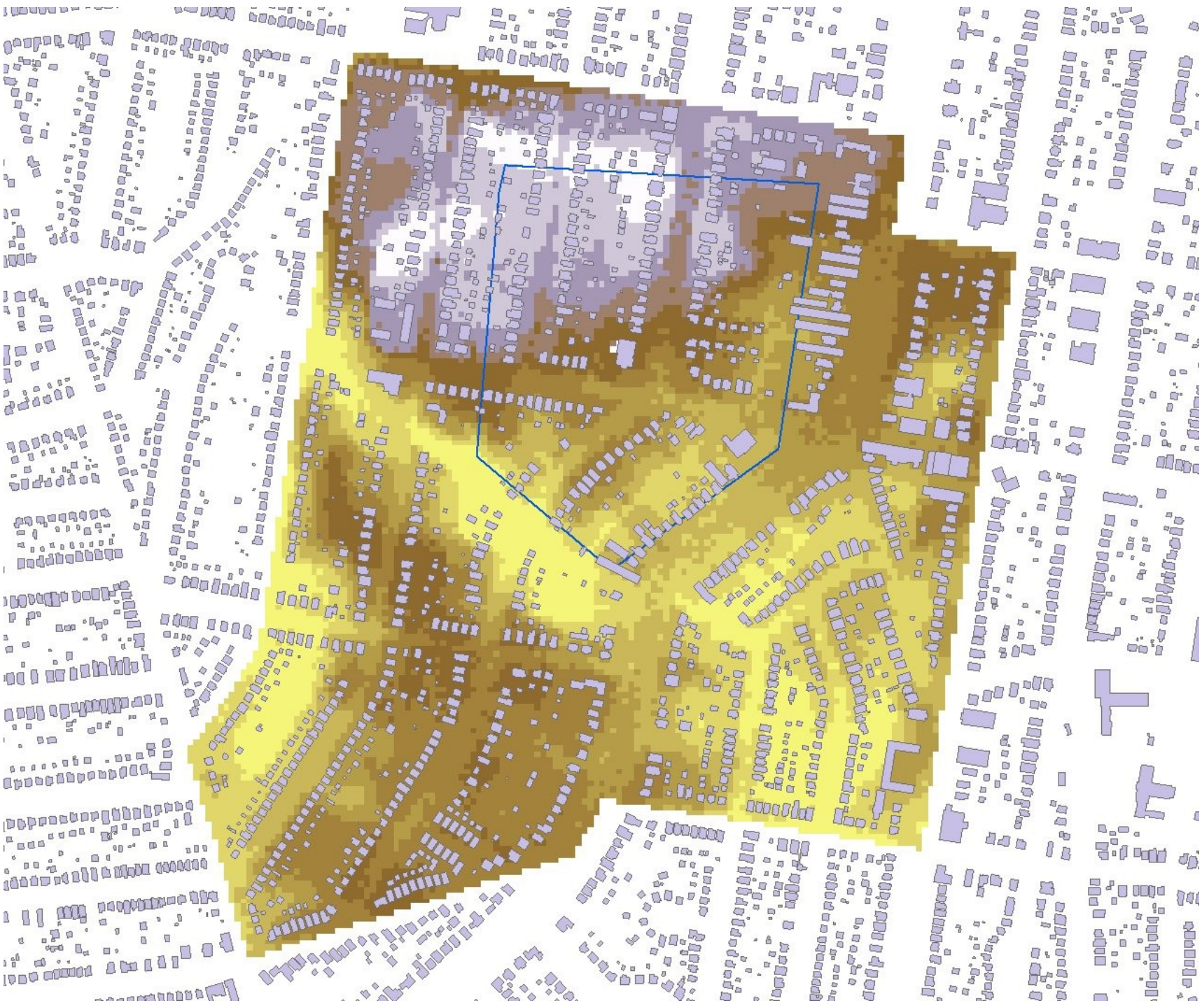
- Initially done by isolating 15 problem areas based on customer complaints and analyzing individually
- In each problem area, sum the discharge volume from adjacent manholes
- Determine ponding capacity by determining volume between successively higher contours
- Worked for smaller events, but for larger events, discharge is not contained in the defined problem area and overflows to adjacent areas

Determination of Surface Flooding Stages and Extents

- Use GRID-based analysis to overcome limitations and account for interactivity between problem areas
- Process:
  - Create Digital Elevation Model (DEM)
  - Aggregate discharge volumes per cell
  - Divide volume by cell area yields depth grid
  - Add depth to elevation creates a stage grid
  - Migrate to lowest point and distribute to equilibrium
  - Convert stage grid to shape file for analysis

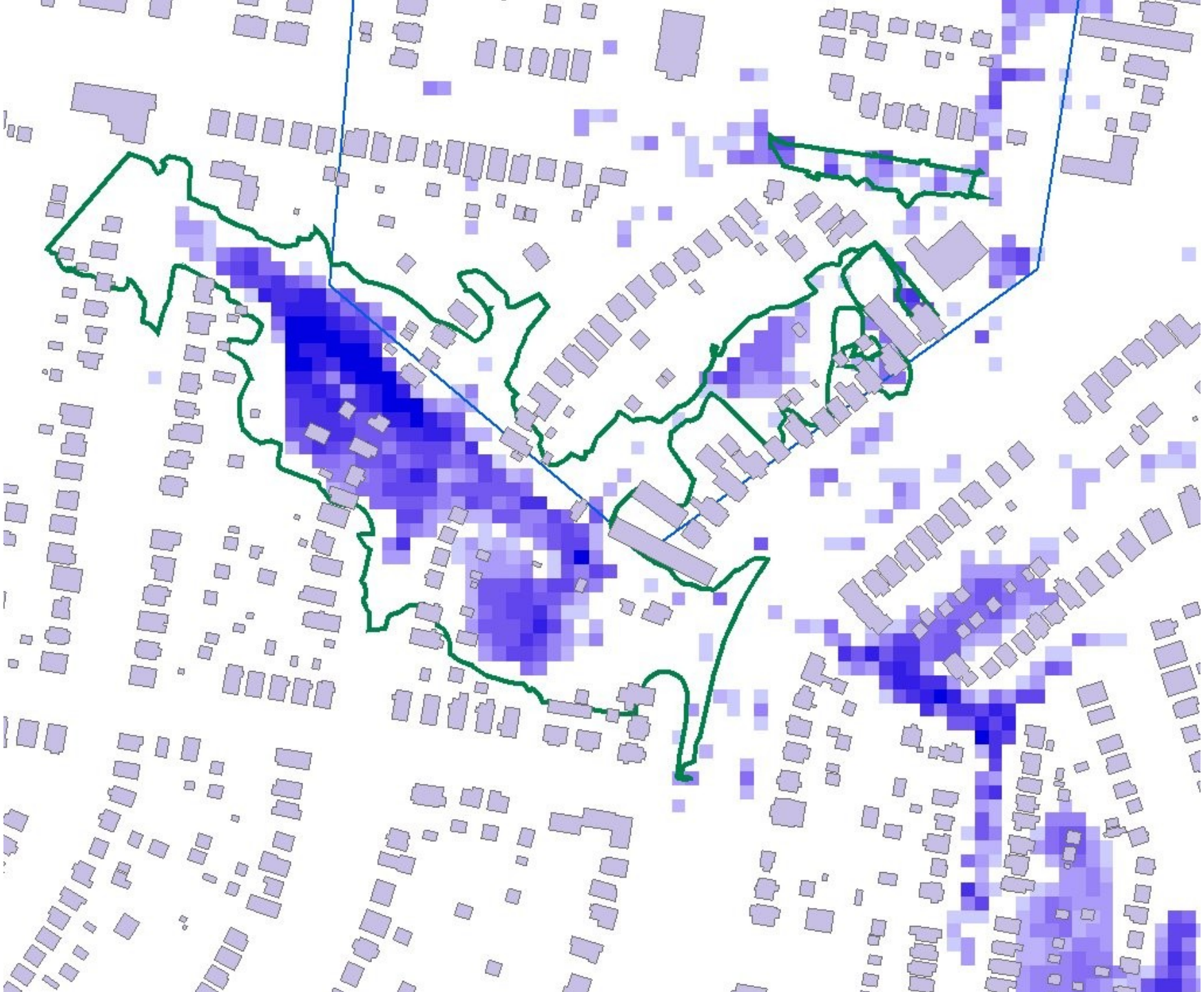
Determination of Surface Flooding Stages and Extents

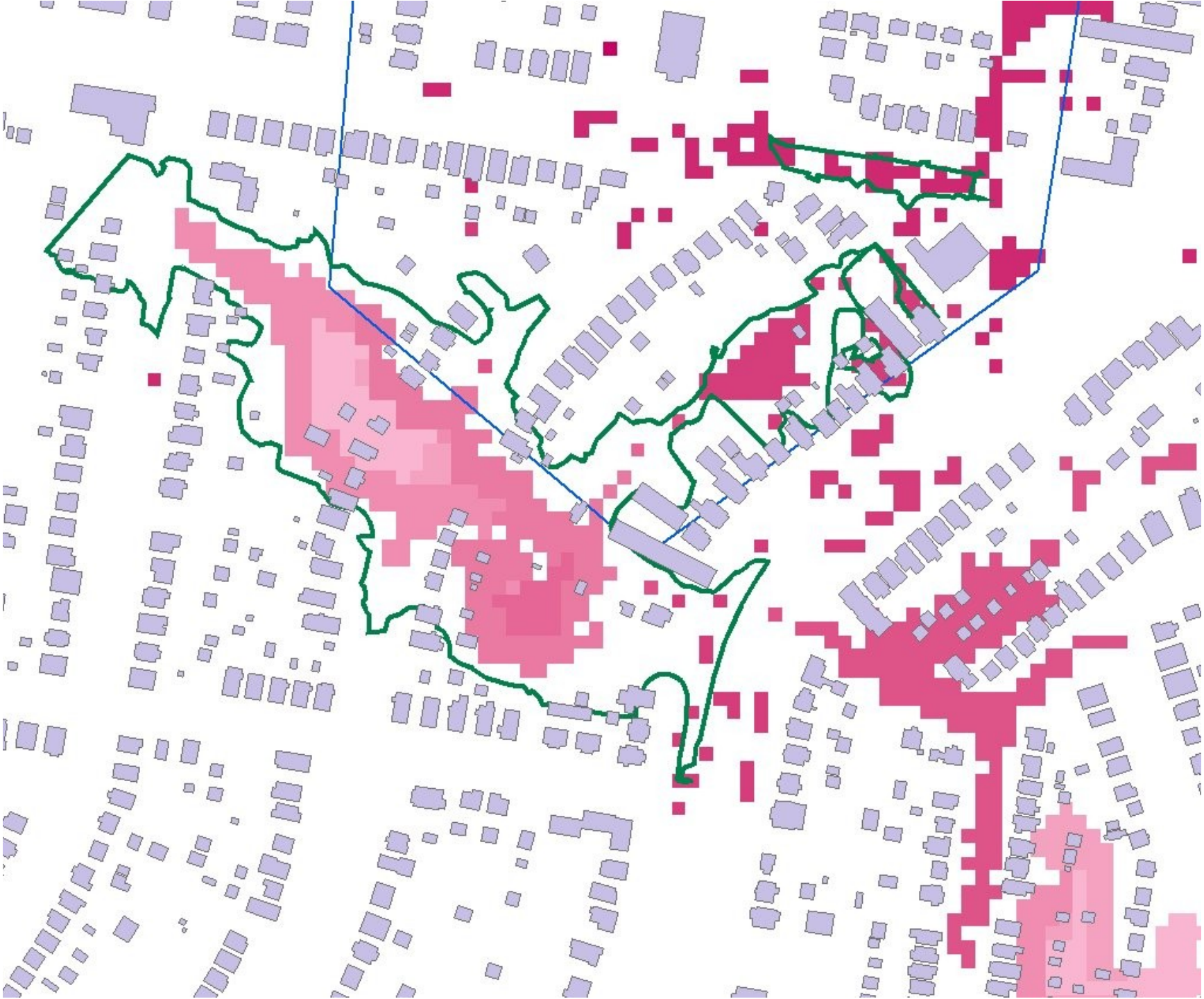
- Create DEM
  - Use inverse-distance-weighting (IDW) algorithm with cell size of 50’

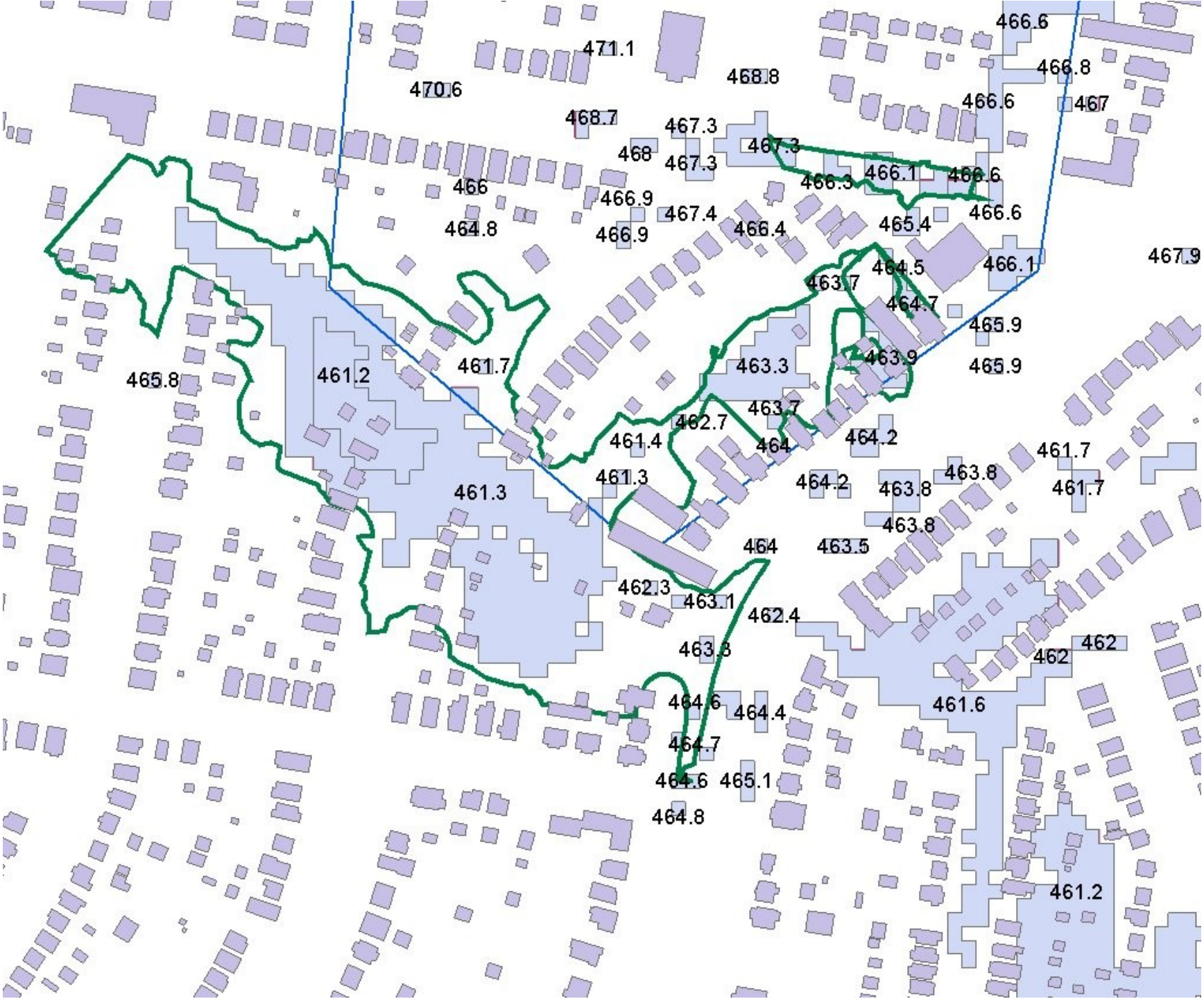


Determination of Surface Flooding Stages and Extents

- Create initial depth grid by summing the discharge from manholes at each cell
- Algebraically add depth and elevation grids to obtain an initial stage grid
- Develop VBA function to migrate columns of water to lowest point
- Develop VBA function to iteratively distribute depths of water to neighboring cells
- Repeat until equilibrium reached



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Link to HEC-FDA

- For each ponding area, developed a stage / frequency table from the GIS application output
- This table was then imported into HEC-FDA providing the final link from SWMM to GIS to FDA

File Edit View Insert Format Tools Data Window Help

Arial 10

N14 =

Copy

A	B	C	D	E	F	G	H	I	J
PONDAREA_ID	LOWPOINT	1YR_NRS	2YR_NRS	5YR_NRS	10YR_NRS	25YR_NRS	50YR_NRS	100YR_NRS	500YR_NRS
NW-001	454.30	454.31	454.32	455.00	455.01	455.02	455.03	455.04	455.05
NW-002	454.60	454.61	454.62	454.63	454.64	454.65	455.10	455.11	455.12
NW-003	455.00	455.01	455.02	455.03	455.04	455.05	455.06	455.07	455.30
NW-004	446.40	447.80	447.81	447.82	447.83	447.84	447.85	447.86	447.87
NW-005	452.10	452.11	452.12	452.80	452.81	452.82	452.83	452.84	452.85
NW-006	454.70	454.71	454.72	454.73	454.74	454.75	454.76	454.77	456.60
NW-007	446.70	446.71	447.00	447.01	447.02	447.10	447.11	447.12	447.13
NW-008	451.70	451.71	451.72	451.73	453.90	454.30	454.80	455.10	455.60
NW-009	449.30	449.31	449.32	449.33	450.30	450.40	450.41	450.42	450.43
NW-010	449.00	449.01	449.02	449.03	449.04	449.40	449.41	449.42	449.43
NW-011	444.60	444.61	444.62	444.63	446.80	446.81	446.82	446.83	446.84
NW-012	449.30	449.31	449.32	449.33	449.34	449.35	449.36	449.37	449.40
NW-013	450.30	450.31	450.32	450.33	450.34	450.35	450.36	451.90	451.91
NW-014	449.20	449.21	449.22	449.23	449.24	449.25	449.26	449.27	450.80
NW-015	450.40	450.41	450.42	450.43	450.44	450.45	450.46	450.47	452.00
NW-016	451.90	451.91	451.92	451.93	451.94	451.95	451.96	451.97	452.10
NW-017	451.30	451.31	451.32	451.33	451.34	451.35	451.36	451.70	451.71
NW-018	450.40	450.41	450.42	450.43	450.44	450.45	450.46	450.47	451.40
NW-019	446.20	446.21	446.22	446.23	446.24	446.25	446.26	446.27	446.40
NW-020	449.20	449.21	449.22	449.23	449.24	449.25	449.26	449.27	450.90
NW-021	449.80	449.81	449.82	449.83	449.84	449.85	449.86	449.87	451.30
NW-022	450.40	450.41	450.42	450.43	450.44	450.45	450.46	452.70	453.00
NW-023	447.50	447.51	447.52	448.20	448.23	448.26	448.30	448.31	448.32
NW-024	447.90	447.91	447.92	447.93	447.94	447.95	447.96	447.97	450.60
NW-025	446.70	446.71	446.72	446.73	446.74	446.75	447.40	447.41	447.42
NW-026	448.30	448.31	448.32	450.10	450.11	450.12	450.13	450.14	450.15

nrs_pond_ids

Results and Conclusions

- GIS allowed techniques to be used that would be impractical otherwise
- Allowed all structures to be examined instead of sampling

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